



US LHC Accelerator Research Program

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Technology development for Nb₃Sn long coils & magnets at Fermilab

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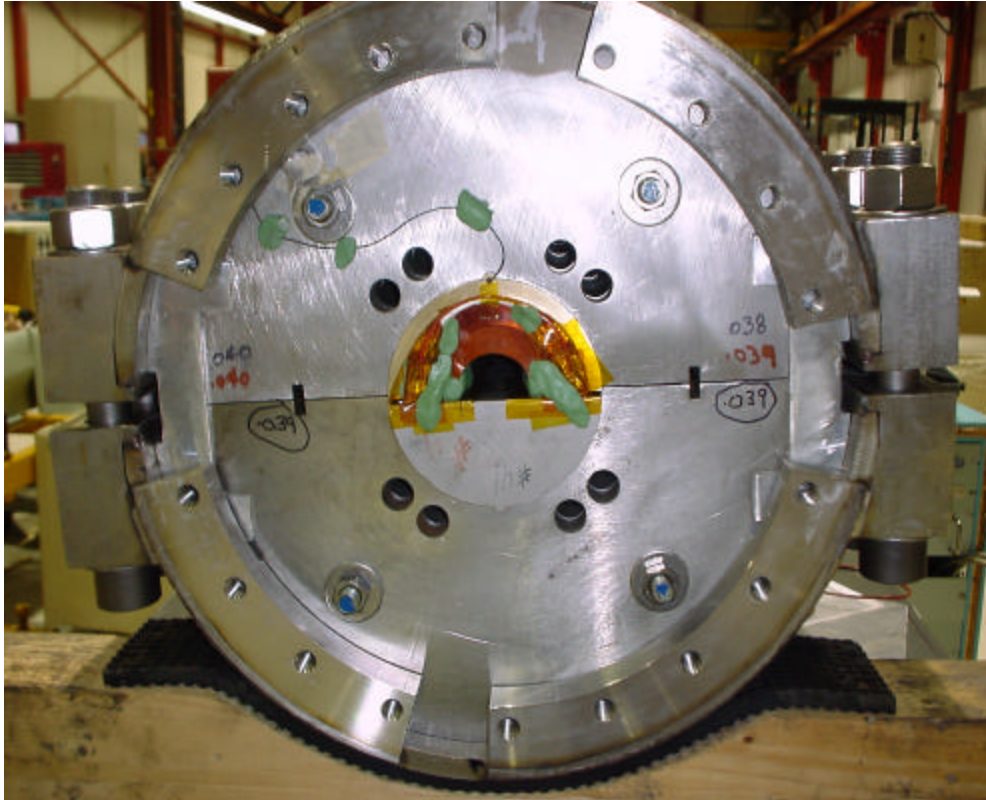


Nb₃Sn long coil technology development

- Development goals
 - Demonstrate an industrial type of technology for coil production **up to 4 meters long**.
 - Fabricate, test and evaluate **2-layer shell-type coil design without internal interlayer splices**
 - Fabricate, test and evaluate **mechanical structures based on collar-yoke-skin support**
- Performance study:
 - **magnet quench performance**: training, re-training, SSL
 - **field quality**: geometrical harmonics, coil magnetization, iron saturation, alignment, field quality correction
 - **quench protection**: conductor parameters, quench heaters
 - **operation margin**: thermal model with mid-plane heaters



Nb₃Sn Dipole in Mirror Configuration – Cheapest Way for Long Coils Study.



Front view of Fermilab mirror magnet HFDM-04.

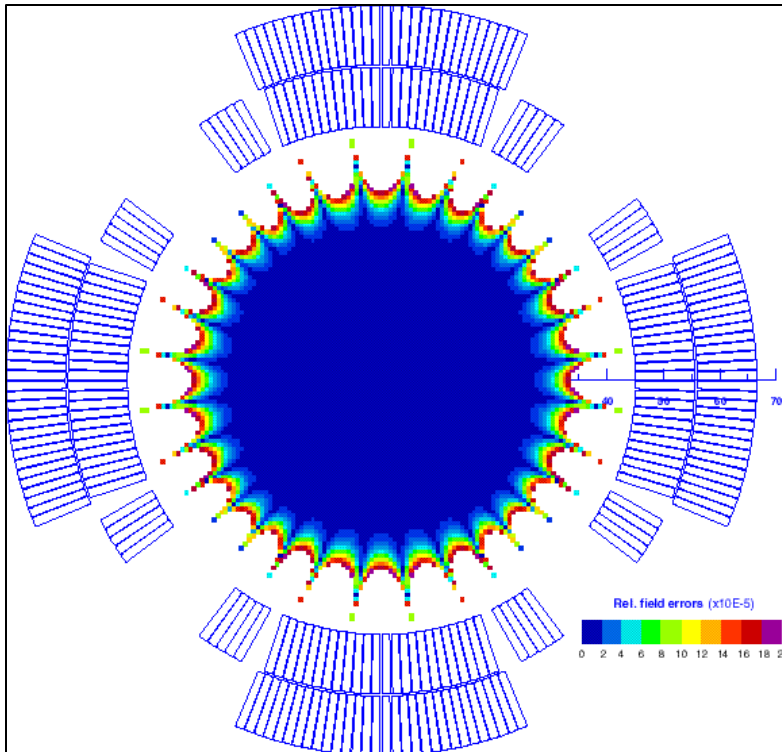
Mirror design uses a one half-coil and an iron half-cylinder as a magnetic mirror to produce the dipole field.

Advantages of mirror configuration :

- It minimizes conductor volume.
- It allows testing long shell-type coils
- It uses available coil winding and curing tooling (winding tables, mandrels, presses, etc.).
- Mechanical structure and tooling exist for 1-2 m long and for long up to 6 m long magnets.



TQa coil – Good Candidate for LARP Long Coil Study



Coil:

- 2-layer shell-type
- Inner-layer wedges
- Inner-layer pole glued into the coil

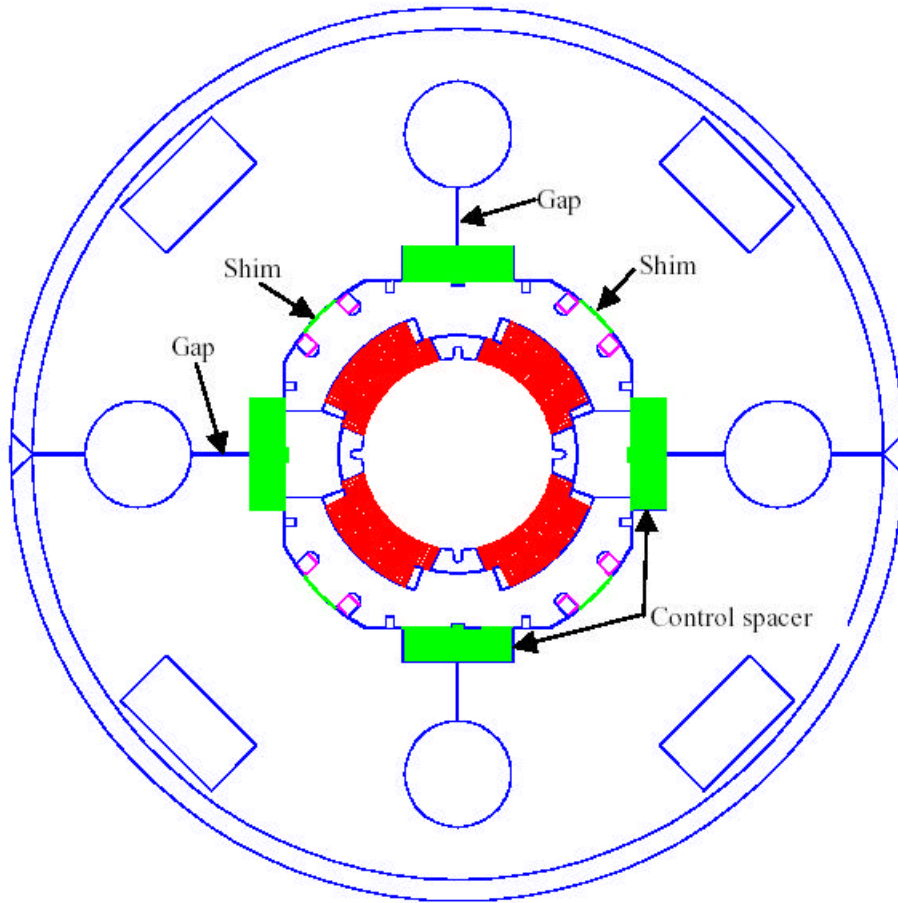
Cable:

- Strand – Nb₃Sn, 0.7 mm
- Number of strands – 27
- Keystone angle – 1 deg
- Width – 10.05 mm
- Thickness – 1.26 mm

Insulation: 0.125 mm.



TQ2a mechanical structure is available up to 6m long.



TQ2a cross-section

Modified MQXB collar blocks with outer-layer poles for coil alignment.

Radial yoke cut per lamination to provide symmetrical load.

Control spacers for collared coil alignment and yoke motion control.

Four shims in the midplanes to control coil-yoke interference.

The 10 mm thick stainless steel skin.

The coil pre-stress remains below 70MPa (100 MPa before the spring back) through all stages of magnet production and operation.



Cost Estimats

Cost estimates for shell-type TQ quad coils and shell-type HFDA dipole coils is summarized in Table

Parameter	TQa	TQa	Mirror	Mirror
Coil length, m	2	4	2	4
Cable cost, k\$	110	220	25	50
Coil & Magnet parts, k\$	115	160	12	42
Tooling modification, k\$	25	100	23	72
T&D Labor cost, k\$	450	550	144	173
Total cost, k\$	700	1,030	204	337

Cost of Long Furnace is not included.



Shell-type long coil program milestones

FY06

- | | | |
|--|-------------|-------------------|
| - Design of 2m long tooling: | FNAL | 02/28/2006 |
| - Procure coil fabrication tooling/parts: | FNAL | 04/30/2006 |
| - Fabricate insulated cable: | LBNL | 04/20/2006 |
| - Fabricate practice coils: | FNAL+ LBNL | 05/25/2006 |
| - Procure collars (modified from MQXB): | FNAL | 05/15/2006 |
| - Assemble 2m mechanical model: | FNAL + LBNL | 07/15/2006 |
| - Design of 4m long tooling: | FNAL | 08/30/2006 |
| - Wind and cure 2m Nb ₃ Sn coils: | FNAL | 08/25/2006 |
| - Procure and install long oven | FNAL | 08/25/2006 |
| - React and impregnate coils: | FNAL | 10/25/2006 |

FY07

- | | | |
|---|-------------|------------|
| - Assemble magnet: | FNAL + LBNL | 01/15/2007 |
| - Test magnet: | BNL + FNAL | 03/31/2007 |
| - Fabricate 4m practice coils: | FNAL+ LBNL | 05/25/2007 |
| - Assemble 4 m mechanical model | FNAL | 08/30/2007 |
| - Wind and cure 4m Nb ₃ Sn coils | FNAL + LBNL | 10/25/2007 |



Summary

- 1) Long TQa coils could be a base approach for long coil technology development.
- 2) Main tooling will be increased in length from 1-2m to 4m by connecting additional blocks. It is more effective way to upgrade tooling without wasting of a previous one.
- 3) Practice coils will be used to improve quality of procedures for coil production and magnet assembly.
- 4) Long Shell-type Coils & Magnet Program for FY2006-07 should be developed and approved in FY2005.
- 5) Long Shell-type Coils & Magnet Program at Fermilab should be started in FY2006.